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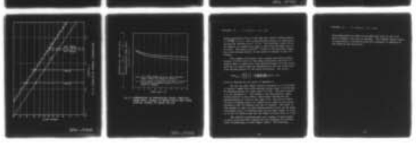

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SUMMARY REPORT

on

SCENICS
PHASE III

Submitted to

Department of the Navy
Bureau of Ships
Code 689B

June 11, 1964

TRACOR INC.
1701 GUADALUPE ST. AUSTIN, TEXAS 78701 GR6-6601

TRACOR, INC. 1701 Guadalupe St Austin 1, Texas

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PHASE III

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June 11, 1964

Prepared by:

(10)
Bruce H. Deatherage, ~~Ph.D.~~
~~Project Director~~
~~Sensory Information Research~~

Donald E. Robinson, ~~Ph.D.~~
~~Senior Psychologist~~

E. A. Tucker
~~ASW Manager~~

Approved by:

Wayne Rudmose
Wayne Rudmose, Ph.D.
Director, Acoustics and
Sensory Information Research

A. F. Wittenborn
A. F. Wittenborn, Ph.D.
Vice President

352 100

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ABSTRACT

Analysis of the results of sensory information experiments comparing the detectability of signals in two visual displays, alike except for being either flat (2-D) or stereo (3-D), shows that a distinct and potentially extremely useful advantage is demonstrated by the 3-D display technique, SCENICS.

When the plane-of-interest (the plane in which signals appear) in the 3-D mode has a noise-marking density the same as the over-all noise marking density (necessarily in the plane-of-interest) in the 2-D mode, the detectability of signals will be greater in the 3-D display.

I. BACKGROUND

In 1963 TRACOR completed an initial investigation of the three-dimensional display technique called SCENICS. In the final report[1] for that work (done under Bureau of Ships Contract NObsr-89265) the following conclusions were made:

(1) "This experiment clearly shows that the over-all marking density for noise alone should be set higher than current practice.

(2) There is, according to this experiment, an indication of an advantage of stereo over flat displays in terms of false alarm rate; the rate for stereo tending to be lower than that for flat.

(3) The experiment showed that tracks were equally detectable in stereo and flat presentations, but it is believed that the result is in part a function of poor depth definition, and in part owing to the method of apportioning the data between the two eyes.

(4) Theoretical considerations, ..., support the belief that the stereo display should show an advantage in detection. The advantage should be capable of being demonstrated in corrected experimental conditions."

The present work confirms those results in general except that a new analysis of the data, on a more valid basis, shows an advantage for the 3-D display, confirming the belief expressed in Conclusion 4.

In the summary Report of NObsr-89265, Task 8100, we pointed out the fact that signal detectability is related to the noise-marking density and that best detection occurred, under the

[1] "Summary Report of Results, Conclusions and Recommendations From a Psychophysical Study of the Relative Detectability of Target Tracks in Simulated Passive Sonar Displays," NObsr-89265, Index Number SF001-03-01, Task 8100, Document Number TRACOR 63-231-U, September 6, 1963.

experimental conditions used, when the 2-D display marking density was 0.60. We now re-emphasize that point, and note that the valid way to compare 3-D vs 2-D is to make comparisons when noise-marking densities in the plane-of-interest, the plane where signals appear, are the same. We will examine this idea in detail later. First, let us examine the results of the experiment.

II. NEW WORK (SCENICS PHASE III)

The psychophysical, or sensory information, experiment under Phase III was undertaken in order to correct the problems which existed in the original research. These problems were of three types: (a) method of obtaining psychophysical data, (b) definition of depth in the visual field, and (c) method of apportioning the simulated sonar data to the two eyes. Detailed discussion of these problems and methods for their solution are found in the Summary Report for NObsr-89265 and in TRACOR's proposal leading to the present work (Appendix A). Briefly, the solutions for the above problems applied in this research are as follows: (a) the psychophysical data for the present research were obtained under the two-interval, temporal forced-choice method which provides control over false alarm rate and produces a large amount of data in a relatively short time, (b) a new and improved overlay was employed which delineated the front plane ("plane-of-interest") of the display through the use of a grid, (c) the method of apportioning the data to the two eyes was changed in such a way that each line of data was matched with lines which preceded and followed it. This had the effect of doubling the binocular fusions from signal-plus-noise relative to the technique used originally and very effectively minimizes the criticism that the 3-D technique was a "data waster."

In addition, and more important than any of the new experimental methods just mentioned, we will use a different method of considering the data. This new method is described in Section V.

III. PROCEDURE FOR THE PSYCHOPHYSICAL EXPERIMENT

Computer printouts were generated for each of nine combinations of output signal and noise-marking densities for both 2-D and 3-D display modes, yielding 18 stimulus conditions. The three output noise-marking densities were 0.30, 0.50, and 0.70. Each of these noise-marking densities was combined with each of three signal densities: 0.10, 0.20 and 0.30. For each of 200 computer printouts generated with an injected signal, there was generated a printout at the same noise-marking density with no signal injected. Thus, for each of the 18 conditions, there were available 200 stimulus-pairs; one printout with a signal and one without. This procedure allows for only a few comparable conditions in the plane-of-interest, but was used for attaining a complete design. The computer printouts were each photographed under a clear overlay on which was printed the visual framework which defined the depth of the visual field. All photographs were made on 35 mm film, developed, and the resulting negatives cut and mounted for projection as 35 mm slides. The projection was done through a device consisting of prisms, mirrors and polarizing lenses which oppositely polarized the two halves of the display and presented them for viewing through 3-D polarized spectacles.

The method used for obtaining the psychophysical data was a two-interval, temporal forced-choice one. In this method, a sequence of two pictures was presented and the observers were asked to state in which of the two pictures they saw a track. One of the two-picture sequence contained an injected track which could be at any one of 18 locations (bearings) within the display. The track, if present, was always injected vertically, i.e., did not change bearing.

Eight observers (undergraduate men students from The University of Texas) were used. They were divided into two

groups of four observers each, and they were trained for approximately three days before the experimental period began. Training consisted of practice on the displays with special attention given to obtaining the 3-D effect. The two groups saw the display modes in a different order for the purpose of balancing out learning effects.

IV. RESULTS OF THE PSYCHOPHYSICAL EXPERIMENT

The results of the sensory information experiments are shown in Tables I and II. All the data from our eight subjects, in all experimental conditions, are presented in the tables.

Table I
2-D MODE

Noise Density \ Signal Density	0.1	0.2	0.3
0.3	55%	72%	92%
0.5	57%	63%	92%
0.7	51%	82%	98%

Cell entries are percent hits. Cell entries under the output signal density of 0.1 are not significantly different from 50%, or chance level.

Table II

3-D, SCENICS MODE

Total Noise Density \ Total Signal Density	0.1	0.2	0.3
0.3	48%	67%	79%
0.5	57%	63%	83%
0.7	42%	69%	97%

Cell entries are percent hits. Cell entries under the output signal density of 0.1 are not significantly different from 50%, or chance level.

The data in these tables confirm our findings in the previous experiment, especially with respect to the relation between hit rate and output noise-marking density. Let us defer any comparison between the 2-D and 3-D modes until we have described a particular method for the comparison.

V. METHOD OF DATA ANALYSIS*

As stated in Section I, the basis for a valid comparison between a 2-D display and a 3-D display is in having equal marking densities for noise alone in the plane-of-interest. The data from the previous experiment showed that, averaged over all signal densities, percent hits increased with increase in marking

*Appendices B and C give brief mathematical treatments of the relation between 3-D and 2-D.

density for noise up to a density of 0.6, then fell rapidly. We can infer from this that in the SCENICS display an overall marking density of $\sqrt{0.6} = 0.774$, giving a marking density in the plane-of-interest of 0.6, would be advantageous because when the input threshold is shifted to raise the overall marking density for noise alone to 0.774 more signal will also be admitted to the display, and we can credit this to SCENICS "processing gain." How much is gained?

Figure 1 shows the data from the previous experiment for a 2-D display. It can be seen that hit rate increases at about 10% per 0.1 noise-marking density. The data of the present experiment show about 5% increase in hit rate with each 0.1 increase in 2-D noise-marking density. We can infer from this that increasing the overall density from 0.6 to 0.774 should yield from 5% to 15% increase in hit rate, because the display is not saturated with the SCENICS technique as it would be in 2-D.

Let us assume that the distributions for noise and, with weak signals, for signal plus noise are Gaussian and have unit variance. The signal-to-noise ratio, (S/N), is then the separation between the means in standard deviation units. For a 2-D display the input threshold, T_f, can be set to yield any desired output-marking density for noise alone, and the output density for signal plus noise will also be determined. A specific example is illustrated in Figure 2, where M_N is the mean of the distribution of input noise alone, and M_{S+N} is the mean of the distribution of the input signal plus noise. A careful examination of Figure 2 will suggest that placing T_f exactly midway between M_N and M_{S+N} would achieve the highest output $\frac{S+N}{N}$, ratio of marking densities, possible. But, of course, it cannot be known in advance what the magnitude of the input signal-to-noise ratio (the distance between the means) will be, so prudence suggests that setting T_f at exactly M_N, giving a 2-D output noise-marking density of 0.5, is the right thing to do. Our

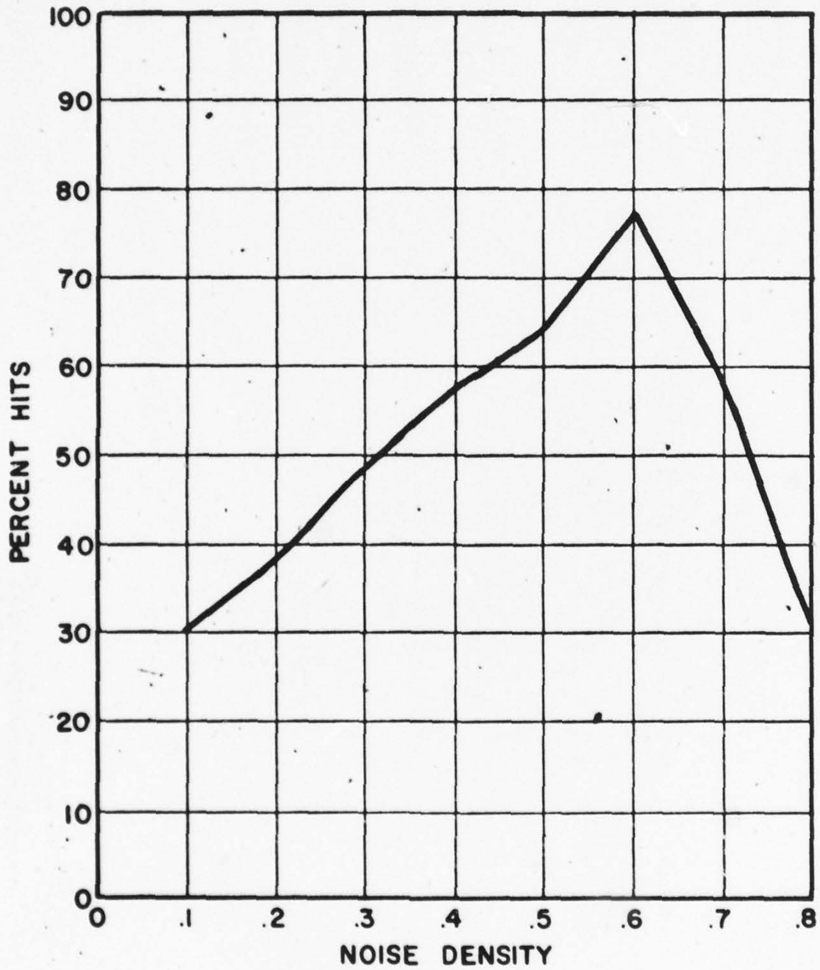

Fig. 1 -COMPARISON OF PERCENT CORRECT RESPONSES (OF TOTAL SUBJECTS) FOR A 2-D BEARING-TIME DISPLAY

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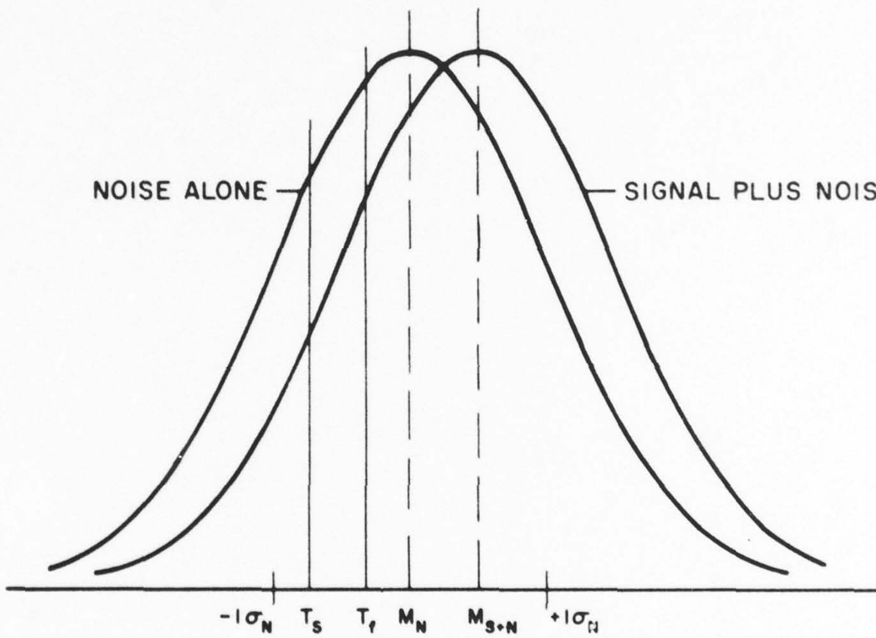

Fig. 2 — DISTRIBUTIONS OF NOISE ALONE AND SIGNAL PLUS NOISE, WHICH HAVE THEIR MEANS SEPARATED BY 0.525 σ UNITS. SEE TEXT FOR FULLER EXPLANATION.

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experimental data, however, indicate higher hit rates for 2-D output noise-marking densities greater than 0.5, which means that T_f should be set lower.

By referring to a table for the normal curve, we can quickly show how the output $\frac{S+N}{N}$ changes for a fixed input (S/N) of 0.525 as T_f is moved from halfway between M_{S+N} and M_N, to M_N, to 0.262σ units below M_N, the last of which yields an output 2-D noise-marking density of 0.604.

Let input (S/N) = 0.525, that is, M_{S+N} is 0.525σ units above M_N. (As we shall see later, an input signal-to-noise ratio in this region is of great interest because it is here that hit rate is changing very rapidly.) First, set T_f between M_{S+N} and M_N, 0.262σ units above M_N and below M_{S+N}. To the right, above T_f, the area under the distribution curve N is approximately 0.396, and input S+N is approximately 0.604. Therefore, the 2-D output marking ratio is

$$\frac{S + N}{N} = \frac{.604}{.396} = 1.525$$

Next, with T_f put at M_N, N = 0.5, S+N = 0.7, the 2-D output $\frac{S+N}{N} = \frac{.7}{.5} = 1.400$.

With T_f put below M_N by 0.262σ units, N = 0.604, S+N = 0.784 the 2-D output $\frac{S+N}{N} = \frac{.784}{.604} = 1.298$. Relatively less S+N area than N area is above T_f as it is lowered.

It should not be forgotten that the input signal to noise, (S/N), was fixed at 0.525 for the illustrations just given.

Now let us see what happens, with the same input (S/N) = 0.525, with the SCENICS technique. To make this process conceputally easier, we will perform the squaring function of SCENICS and examine only the output in the plane-of-interest. Operationally, this function could be done either completely visually, as in SCENICS, or by having only the plane-of-interest data suitably written out on another 2-D display.

In Figure 2, again, suppose T_f is as shown, i.e., 0.262σ units below M_N, making the marking density N = 0.604 and S+N marking density = 0.784. The position, T_s, of the threshold for a 3-D display having the same noise-marking density in the plane-of-interest is $\sqrt{0.604} = 0.777$. A normal curve table shows that an area of 0.777 lies above a $T_s = 0.762\sigma$ units below M_N. T_s is so drawn on Figure 2. T_s is 1.287σ units below M_{S+N} which corresponds to an area of about 0.901. Thus, the 3-D output $(S+N/N)^2 = (0.901/0.777)^2 = 0.812/0.604 = 1.344$. The same (S/N) in 2-D, with N = 0.604 gave a ratio of output S+N/N = 1.298. This difference corresponds to an increase in the output(S/N) for the 3-D mode. By referring to the table for the normal curve again, for areas equal to 0.812 for S+N and 0.604 for N we find that this represents an effective (S/N) = 0.623 as compared to the input (S/N) = 0.525. If the rule of 5% to 10% increase in hit rate for each 0.1 increase in N is valid, the SCENICS display should yield perhaps as much as 10% higher hit rate than the best hit rate from 2-D at 0.6 noise-marking density. This measurement remains to be done.

Figure 3 is a smoothed, and perhaps somewhat idealized curve for the raw percent hits data of the present experiment against input signal-to-noise ratio. The two (S/N) values, 0.525 and 0.623, fall on the curve about 7% apart. It was previously remarked that the region of input (S/N) = 0.525 is of interest because of the rapidity of change of the hit rate. The crosses on the figure mark the experimental values. It is probably a good inference that, for displays of the type used, when the input signal-to-noise ratio falls to 0.4 or less, the detection, of signals is a chance affair, while hit rate increases rapidly above this value.

Table III shows the input (S/N) for each of the marking densities used in the experiment, which is also the output

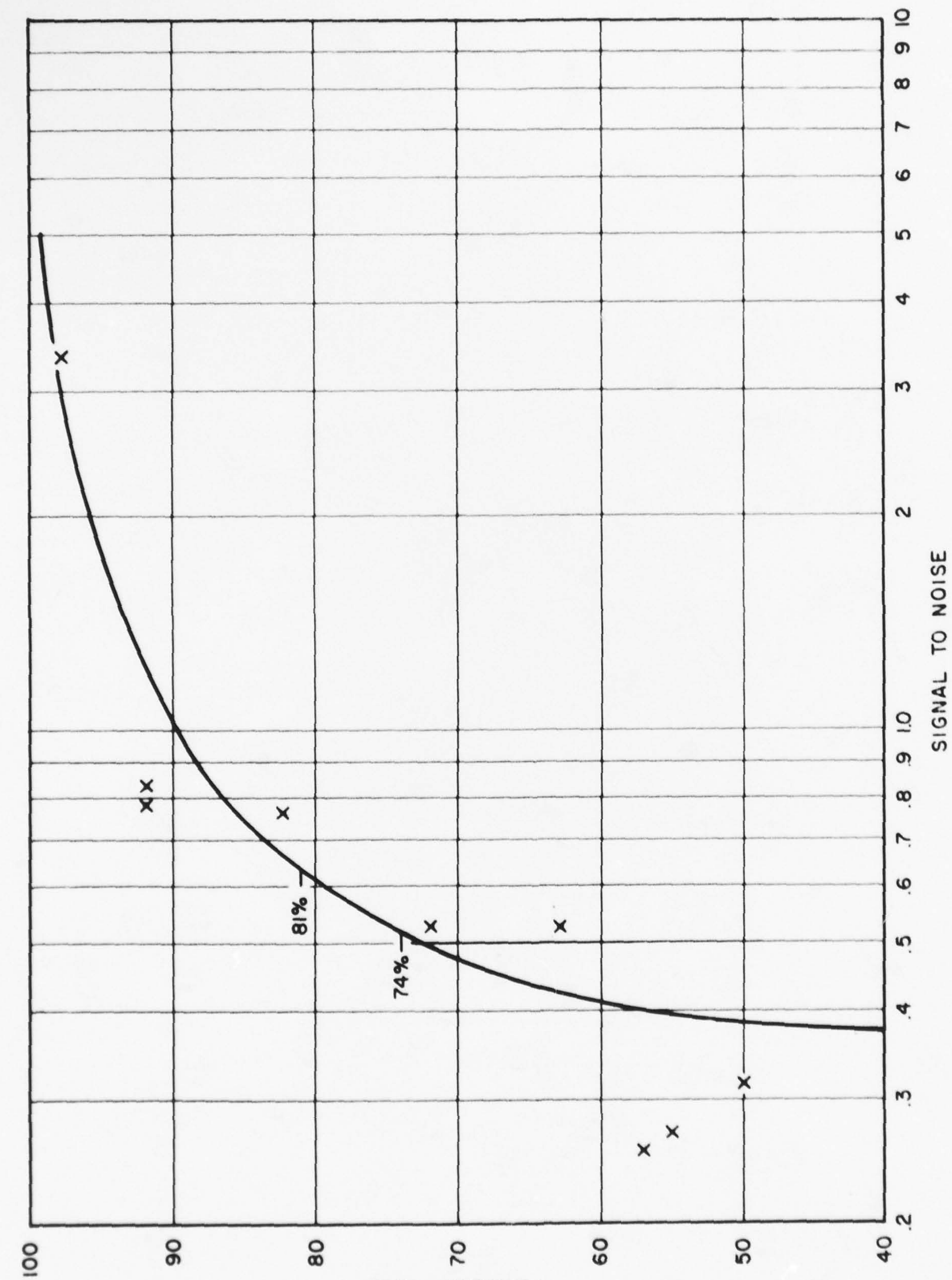

Fig. 3

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marking density for the 2-D mode. Table IV shows the output-marking densities for the 3-D mode of display. The relation between values in Tables III and IV makes it evident why a higher hit rate can be expected for the SCENICS display.

Table III

INPUT (S/N) FOR BOTH 2-D AND 3-D, OUTPUT (S/N) FOR 2-D

Noise \ Signal	0.1	0.2	0.3
0.3	(S+N)=0.4 0.270	(S+N)=0.5 0.525	(S+N)=0.6 0.780
0.5	(S+N)=0.6 0.255	(S+N)=0.7 0.525	(S+N)=0.8 0.841
0.7	(S+N)=0.8 0.316	(S+N)=0.9 0.760	(S+N)=1.0 3.345 and greater

Table IV

OUTPUT (S/N) FOR 3-D IN THE PLANE-OF-INTEREST

Noise \ Total Signal	0.1	0.2	0.3
$(0.3)^2=0.09$	$(S+N)^2=0.16$ 0.340	$(S+N)^2=0.25$ 0.665	$(S+N)^2=0.36$ 0.982
$(0.5)^2=0.25$	$(S+N)^2=0.36$ 0.317	$(S+N)^2=0.49$ 0.650	$(S+N)^2=0.64$ 1.030
$(0.7)^2=0.49$	$(S+N)^2=0.64$ 0.380	$(S+N)^2=0.81$ 0.903	$(S+N)^2=1.0$ 3.845

VI. CONCLUSIONS

The simplest way to state the conclusions of the present work is to compare the results with those of the first experiment:

(1) As in the earlier work, we have found that the best detection does not occur with the lowest noise-marking densities. On the contrary, we again find that a marking density of 0.70 yields the highest detectability for signal densities of 0.20 and 0.30.

(2) In a two-interval forced-choice experiment such as the one performed here, a reduction in false alarm rate must be reflected in an increase in hit rate. To the degree that Conclusions 3 and 4, below, are true, higher hit rates for the 3-D display will be accompanied by lower false alarm rates.

(3) The results obtained in the present experiment with a more efficient psychophysical method, with improved depth definition, with a new method of apportioning the data between the eyes and with a new method of data analysis leads us to conclude that there is a demonstrated advantage of a 3-D display over a 2-D display for signal track detection.

(4) The 3-D type display has a greater input data capacity than the 2-D type display.

VII. RECOMMENDATIONS

TRACOR recommends that (1) exploitation of the demonstrated advantages of the SCENICS display technique commence as soon as practicable. The initial step should be the development of an experimental "live" display which can be fed computer simulated

data or data recorded at sea. (2) Analytical and experimental work should be initiated to adapt the SCENICS technique to an active sonar system. An active sonar system which has a very high rate or large storage capacity for several successive cycles is the most appropriate kind.

APPENDIX A

Design of an Experiment in Pattern Detection in a Stereoscopic Display

INTRODUCTION

Mathematical considerations make it reasonable to believe that the stereoscopic (three-dimensional) presentation of sonar data will lead to higher detectability of signals in noise than would be the case in a flat (two-dimensional) display. The relation between stereo and flat can be computed by

$$\text{Signal Enhancement} = \frac{\Delta_p^{\,2} + p(\Delta_p)}{p^2}$$

where p is the probability of marking by noise alone and Δp is the probability of marking by the signal.

Another way of stating the relation is the ratio between the signal-to-noise ratios of stereo and flat:

$$R = \frac{p' + p}{p(1+p)}$$

(See appendix to our Summary Report for complete statements of the derivation of the SE equation and R.)

An experiment was performed which was to demonstrate this expected advantage. In fact, it did not, although it had other useful outcomes, as stated in the Summary Report already referred to. We believe, from reports of our subjects and from our own experience, that the failure was in part owing to poor definition of the plane-of-interest in the visual field.

Of more importance, half the potential signal-plus-noise binocular fusions were "thrown away" by the method of printing the simulated passive sonar data. These fusions may be included

by visually matching each line of data with lines which precede and follow it, thus:

Left Eye Odd numbered time-samples.	Right Eye Even numbered time-samples.
A-------------------------	A'-------------------------
B-------------------------	A'-------------------------
B-------------------------	B'-------------------------
C-------------------------	B'-------------------------
C-------------------------	C'-------------------------
D-------------------------	C'-------------------------
D-------------------------	D'-------------------------

METHOD A

The method used in the original experiment was

A-------------------------	A'-------------------------
B-------------------------	B'-------------------------
C-------------------------	C'-------------------------
D-------------------------	D'-------------------------

METHOD B

and so if a mark from $p + \Delta p$ appeared in A', say, and in B, but not B', the chance for binocular fusion is used in Method A but not Method B. Method A, furthermore, does not increase the percentage of fusions from noise alone because the number is still determined by p^2. Moreover the absolute visual extent vertically of the stereo presentation is the same as the flat display (where the straight vertical sequence A, A', B, B', etc. is shown) in Method A whereas it is only one-half so great in Method B.
We will not confuse the data on pattern detection by using displays of different dimensions with Method A.

Of lesser importance, the experimental design made prohibitive the taking of sufficient data to obtain high reliability (i.e., reduce the variance). Additionally, there was insufficient control over false alarm rate. All these defects can be remedied.

1. The depth of visual field can be better defined. We will draw and assess a number of "visual frame works," and select the best for use in the experiment proper.

2. Based on our experience, a new and greatly improved experimental design has been chosen (see METHOD section) which, using the accepted theory of signal detectability (TSD) techniques, will yield large amounts of data of high reliability in a relatively short time.

3. False alarm rate is controlled, also through the use of TSD techniques.

4. Method A of utilizing the simulated sonar data for binocular display will be used.

THE PROBLEM

The problem is to demonstrate the theoretical advantage of the stereo (SCENICS) display technique over the conventional flat display.

METHOD

A two-category, forced-choice method will be used. Two independent blocks of simulated data will be presented in temporal succession to subjects (Ss) on each trial, and they will be asked to respond by indicating in which block a signal track was shown. A track will be always present in one or the other, but never both. Ss will also indicate the location of the tracks they call.

There are to be nine basic conditions, replicated in 2-D and 3-D forms. The nine conditions are formed by a 3x3 matrix:

three signal densities, .10, .20, and .30, and three noise densities, .30, .50, and .70. Ss will make 300 judgments in each condition for a total of 5400 over-all conditions and forms (300x 9x2). The judgments, at approximately 15 seconds per trial, will take about 72 hours running time for 6 Ss, 3 at a time. Ss and conditions will be so used as to counterbalance the effects of order. Practice effects will be minimized through a program of preliminary familiarization.

Computer print-outs will simulate the blocks of sonar data. To simulate the flat display blocks, areas 50 lines wide by 50 lines long will be printed. Exactly the same data marks will be printed twice, the two side by side, so that the display, while still appearing as flat, will in all other respects be like the stereo display. For the stereo cases, data blocks will be printed in accordance with Method A as described earlier, and will appear as 50 lines wide by 50 long, that is, they will contain exactly the same amount of data as do the blocks for the flat cases.

Blocks of data will be photographed with high contrast film and projected on a screen with polarized light to permit three Ss at a time to make their independent judgments simultaneously.

The results of the Ss judgments will yield measures of pattern detectability, d', with false alarm rate controlled.

APPENDIX B

For a flat, thresholded input, display, let the marking probability for noise alone be p. The mean number of marks in m trials is then mp and the variance is mp(1-p). The marking probability is determined by a threshold T_f set on a Gaussian process, of mean m and standard deviation of unit, such that

$$p = \frac{1}{2\pi} \int_{T_f}^{\infty} e^{-\frac{(x-m)^2}{2}} dx$$

When a signal is present, the mean of the Gaussian process changes to m'>m and the standard deviation remains unchanged to a first order approximation when m' is only slightly greater than m. The marking density, p', for signal plus noise is then

$$p' = \frac{1}{2\pi} \int_{T_f}^{\infty} e^{-\frac{(x-m')^2}{2}} dx,$$

with p'>p.

On the display, the output signal-to-noise ratio for m trials can be defined as the change in the expected number of marks due to signal over the standard deviation of the number of marks for noise alone. This is

$$(S/N)_f = \frac{m\,(p' - p)}{p(1 - p)} .$$

For a stereo display, we want to maintain the same noise-marking density, p, in the plane-of-interest. This means that we need to alter the threshold T_f to T_s, such that the new flat marking probability P is

$$P = p \quad .$$

This is obtained by adjusting T_s to a value such that, for noise alone,

$$P = \frac{1}{2\pi} \int_{T_s}^{\infty} e^{-\frac{(x-m)^2}{2}} dx .$$

The corresponding signal-marking density is

$$p' = \frac{1}{2\pi} \int_{T_s}^{\infty} e^{-\frac{(x-m')^2}{2}} dx .$$

The marking process in the plane-of-interest is again governed by the binomial distribution, so that

$$(S/N)_s = \frac{m\ (P'^2 - p)}{p(1 - p)} \quad .$$

The ratio, R, of the two display output signal-to-noise ratios is then, letting $P'^2 = p'_s$.

$$R \equiv \frac{(S/N)_s}{(S/N)_f}$$

$$\equiv \frac{(p'_s - p)}{(p' - p)} = \frac{\frac{p'_s}{p} - 1}{\frac{p'}{p} - 1}$$

The relative value of the stereo display in terms of output signal-to-noise ratio thus depends on the change of noise signal

marking density p_s' and noise-marking density p relative to p' and p as the threshold is changed. The actual hit rate will, in both cases, depend on the absolute value of p.

APPENDIX C

The previous appendix presented the properties of the output signal-to-noise ratio in terms of the marking densities on the 2-D and 3-D displays. An alternative approach to the discussion of processing gain can be constructed by comparing the input signal-to-noise ratio $(S/N)_3$ resulting in a given noise-marking density in the plane-of-interest using the 3-D technique with the input signal-to-noise ratio $(S/N)_2$ resulting in the same noise-marking density in the 2-D display.

The most convenient process involves the use of the cumulative Gaussian plots shown in Figure 4. These plots represent the area under the Gaussian curve to the right of the threshold T. A marking density of 50% is obtained for the noise alone by placing the threshold at M, the mean noise signal. The plot which intersects the 50% level at M + 0.525 represents the noise plus a signal which increases the mean by 0.525. This point is marked

$$(S/N)_2 = 0.525 \quad .$$

and corresponds to a signal power S,

$$S = (0.525)^2 = 0.275.$$

expressed in units of the standard deviation of the noise distribution.

The example given in the report is illustrated in the plot. Setting the threshold at M = 0.262 results in a marking density (2-D) for noise alone of 0.604 and a marking density for the signal plus noise of 0.784. These points are marked by the black circles in Figure 4. The situation for the 3-D display is also shown. The marking density for noise alone in the 3-D

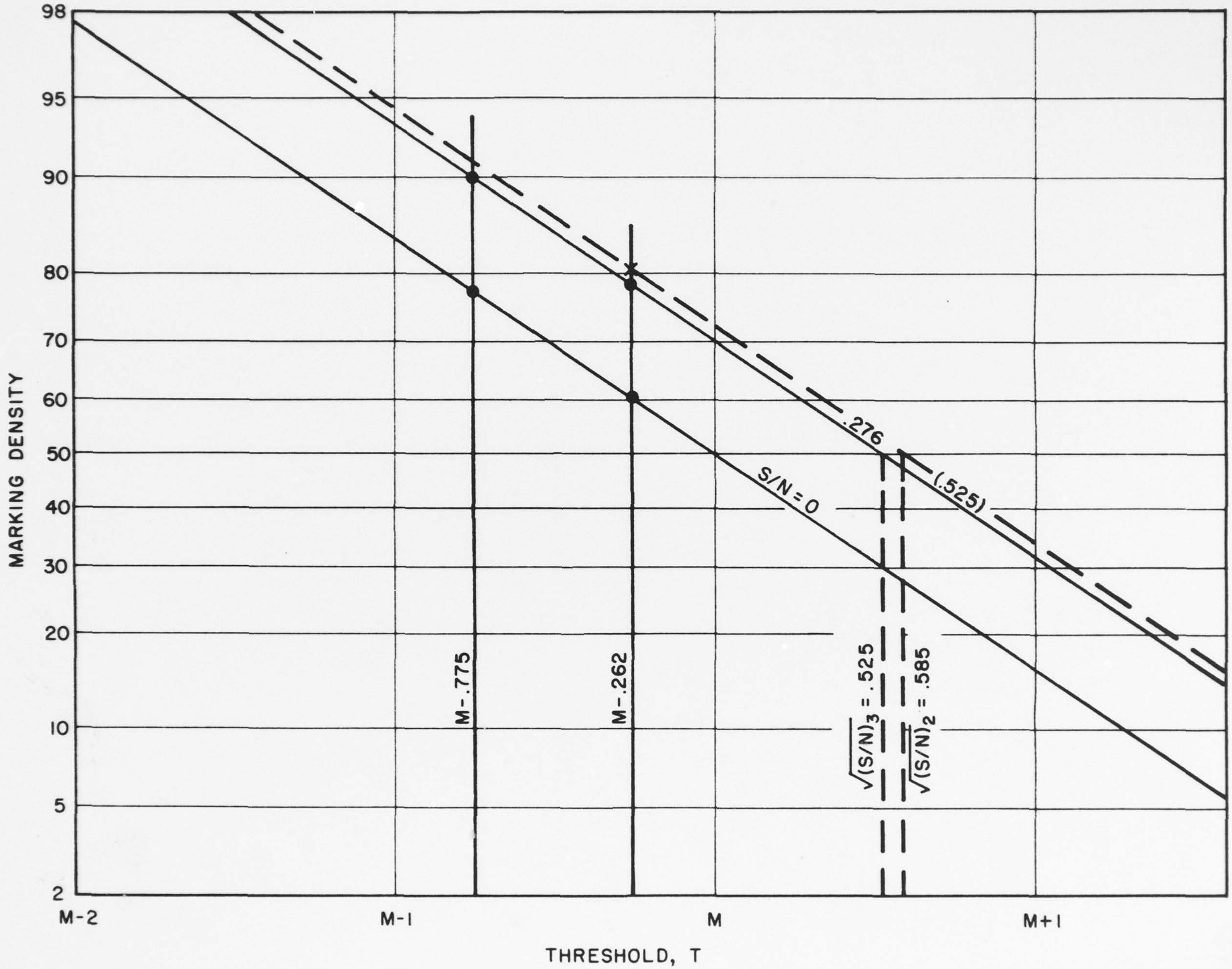

Fig. 4 -CUMULATIVE NORMAL DISTRIBUTION

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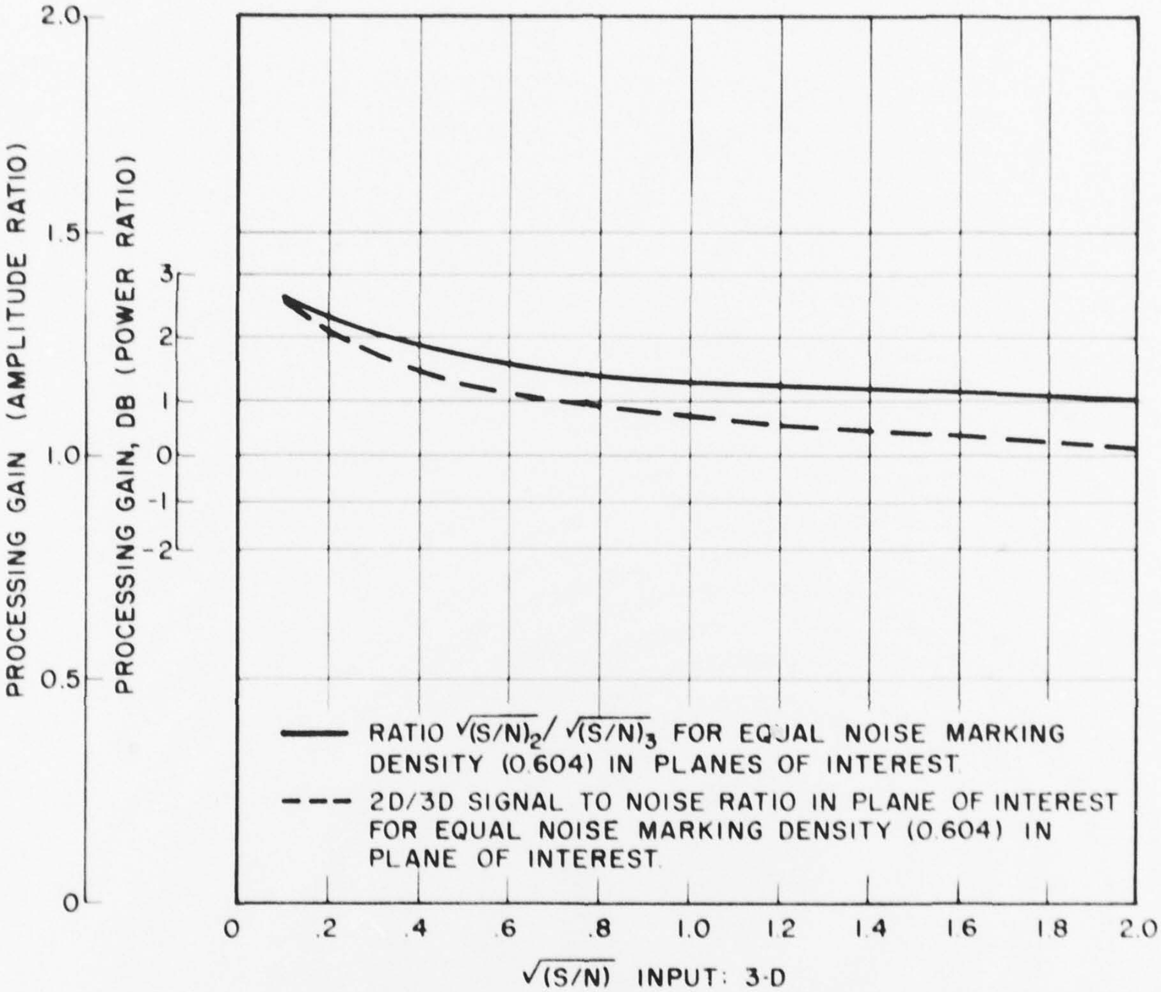

Fig. 5 – COMPARISON OF PROCESSING GAINS COMPUTED FROM INPUT SIGNAL TO NOISE RATIO AND FROM DISPLAY SIGNAL TO NOISE RATIOS.

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plane-of-interest will be 0.604 when the overall marking density is $\sqrt{0.604} = 0.777$. This overall marking density is obtained by setting the threshold at M - 0.775. The resultant overall marking density for signal plus noise is read from the upper plot to be 0.901. The square ($[0.901]^2 = 0.812$) is the resultant signal plus noise-marking density in the plane-of-interest in the 3-D display.

This example illustrates that a signal plus noise marking density of 0.812 occurs in the plane-of-interest with the 3-D display while a signal plus noise-marking density of 0.784 occurs with the 2-D display when the thresholds are set for 0.604 noise alone marking density in the plane-of-interest. The ratios

$$(S/N)_{out} = \frac{p_s'/p - 1}{p'/p - 1} = \frac{0.812/0.604 - 1}{0.784/0.604 - 1} \cong 1.157$$

would be obtained by the result of Appendix B.

One may ask what signal would be necessary in a 2-D display to obtain a signal plus noise-marking density equal to 0.812 when the marking density for noise alone is 0.604. The point marked x at the threshold T - .262 defines a new distribution, shown dotted parallel to the others, which passes through the 50% marking density at 0.585 to the right of M. The ratio (0.585)/(0.525), or perhaps better its square, can be taken as the processing gain of the 3-D display over the 2-D display. The point of this example is that the same marking density occurs in the plane-of-interest with a 3-D display when the rms input signal is 0.525 as in the 2-D display when the rms signal-to-noise ratio is 0.585.

The expected processing gain for a number of input signal-to-noise ratios has been computed by this technique by plotting lines corresponding to other signal levels. The resulting

processing gains are shown as an amplitude ratio by the solid plot in Figure 5 and also in decibels. The display output signal-to-noise-ratios, calculated using the techniques of Appendix B, are shown by the dotted plot.